NASA TECHNICAL MEMORANDUM

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SURFACE-MOUNTED FLAT CONDUCTOR CABLE FOR HOME WIRING

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TABLE OF CONTENTS

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LIST OF ILLUSTRATIONS

TECHNICAL MEMORANDUM X-64887

SURFACE-MOUNTED FLAT CONDUCTOR CABLE FOR HOME WIRING

INTRODUCTION

When flat conductor cable (FCC) for home wiring is first discussed with someone, their first two questions are usually: (1) Why is NASA involved in house wiring? and (2) Is it safe? What happens if you drive a nail through it? The first question is usually "not-voiced" — just a look of puzzlement and curiosity. The second question comes through loud and clear, with definite tones of doubt and concern. Both of these questions, and others, will be answered in the following pages of this report.

Even though NASA missions are space oriented, this is not the first time that commercial applications and spin-offs have evolved from NASA projects. By encouraging secondary applications of aerospace technology, NASA is reducing industry's duplication of research effort, while increasing the return on the taxpayer's investment in the national space program.

The NASA Technology Utilization (TU) Program was specifically established to identify and transfer NASA technology to the public sector. To accomplish this, each NASA center has a TU Office which works jointly with the Headquarters TU Office in Washington, D.C. The Headquarters TU Office, through an Urban Development Application Project (UDAP), is helping the overall building industry by applying aerospace technology to many construction problems. Abt Associates, Cambridge, Mass., was commissioned to carry out UDAP. Through their discussions with the New York Urban Development Corporation, and other building organizations, it was made known that drastic improvements and changes must be made in home wiring to cope with increasing material and labor cost, increasing electrical demands, new building materials, new concepts of building, and rehabilitation of old buildings. The NASA flat conductor cable development group was contacted and asked if FCC might be an answer to some of the home wiring problems. As a result, engineers at Marshall Space Flight Center (MSFC), through the various TU Offices, began actively pursuing the application of FCC technology to a surface-mounted home wiring system. The new system, which is now in the prototype phase, will satisfy the wiring requirements throughout the entire house, e.g., the kitchen, the dining room, the den, the bedroom, and the bath. The planned system will be total FCC, from where the service line enters the power panel (such as the concept shown in Figure 1), throughout the house (to lights, switches, and special wiring; including telephones, intercoms, and alarms), to where the system interfaces with standard plugs (Fig. 2) or equipment and appliance terminations.

In developing the new system, four things must be achieved:

1. It must reduce overall cost.

2. It must be functional.

3. It must be as safe or safer than present electrical systems.

4. It must be aesthetically acceptable.

MSFC engineers feel that such a system is not only feasible, but will be developed in the next few years. It is interesting to note that FCC for home wiring is not new. In 1884, Charles Temple Jackson was granted the first patent for FCC for home wiring. He laminated flat copper conductors between thin strips of paper, and cemented it to the wall. Now flat conductor cable is usually made of rolled or slitted flat conductors laminated between thin, flexible, plastic, insulating films. Up until 1971, practically nothing had been done to adapt FCC to home wiring. There had been some communication and electronic console type applications, but these were mostly low voltage with small conductors. The time is now right to revolutionize our home wiring systems. The materials and manufacturing know-how are available; a surface-mounted flat conductor cable system can be the answer.

BASEBOARD CONCEPTS

So far, MSFC engineers have considered two typos of baseboard systems for distribution of power throughout a given room, or the entire house if need be. The first is a snap-on cover system (Fig. 3). A typical installation sequence would be as follows:

1. Install wall clips or other suitable attachment hardware.

2. Route and install cable. Note that this is done by layers, and the circuit is continuous — no joints, except at the beginning or end of a run.

3. Attach receptacles at desired locations.

4. Snap on appropriate corners, inside and outside.

5. Cut baseboard to proper length.

6. Remove knock-outs from baseboard mold to align with the receptacle face.

7. Snap on baseboard mold.

Receptacle attachment for the snap-on cover system can be made by several methods, including crimping, soldering, riveting, and stapling (Fig. 4), or by pressure contact on the "bared" conductor (Fig. 5), or even through the insulation.

The snap-on baseboard system will accommodate several layers of cable, probably up to six without difficulty. It can be put on the market quickly because very little development is needed and the design is simple. It would require more on-site installation man-hours than an extendable baseboard system (Figs. 6 and 7).

The components for the extendable baseboard system would be factory-made — maybe automated to eliminate manual labor. Typical components would be inside corners, outside corners, end caps, adapter junctions for FCC, adapter junctions for round wire, and extendable baseboard sections which come complete with receptacles. The extendable sections would be available in several sizes so that any wall length can be fitted. The concept shown in Figure 6 has receptacles for standard three-prong plugs. The system shown in Figure 7 is much thinner and requires an adapter which plugs into the top of the extendable section. A typical installation sequence for either extendable baseboard system would be as follows:

1. Install attachment hardware — simple clips or snaps, maybe an adhesive on the baseboard back, with peel-off paper.

2. Plug the components together.

3. Telescope the sections to length.

4. Place onto the wall.

As can be easily seen, the extendable system will require more development and design than the snap-on system. It has more joints, which means that each joint must be highly reliable; but even with the extra joints (two per corner per conductor), the FCC extendable baseboard will have fewer connections than existing round wire systems, which have at least two joints per receptacle per conductor.

SAFETY ASPECTS

Surface-mounted FCC home wiring systems will be safe — equal to or better than existing home wiring methods. Although FCC is completely "electrical-compatible" with home wiring requirements (voltage, current, insulation resistance, etc), some problems do exist in making it safe and minimizing electrical shock.

There are three controlling factors which determine the physiological effects of electrical shock on people:

1. Body weight.

2. Current through the body.

3. Duration of shock.

The physiological effects of electrical shock (Fig. 8) vary from barely susceptible sensation to death. The effects shown in Figure 8, and the corresponding milliamp levels, apply to most people, but not all. Most people can "let-go" a hot wire at 16 mA or less. Ventricular fibrillation usually causes death between 100 and 200 mA and, surprisingly, in the 200 to 1000 mA range, severe muscular contractions forcibly clamp the heart and protect it from damage. Survival is good if immediate medical aid is given.

Making FCC safe without using expensive raceways and conduit is within the state-of-the-art. Several techniques are available by which an FCC home wiring system can be made safe:

1. Inaccessibility — This method reduces the probability of a person being accidently shocked. Routing of the cable in corners, above reach-height, at top of walls, on ceilings, in the attic, and in closets are typical examples.

2. Protective Coverings — It is obvious that metal raceways could be used for routing FCC, but this would not be compatible with lower cost nor aesthetic goals. Figure 9 shows a cross-sectional view of how a cable with a "grounded shield" can be installed — surface mounted; the thickness to width ratio is exaggerated for clarity. The shield offers mechanical as well as electrical protection and will serve as a safety measure, but it has the disadvantage of making the cable about 0.51 mm (20 mils) thicker, which makes it more difficult to hide under wall coverings such as paint and paper. Engineers have tested the "grounded-shield" concept and found that it works. With the test setup shown in Figure 10, several hundred penetrations were made using a nail and hammer. A very sensitive memory oscilloscope did not detect any voltage potential between the nail head and ground. As the nail penetrates the shield and the hot conductor, a short is made which will trip any proper protection device, and because the nail makes continuous contact with the grounded shield, there is no possibility of electrical shock.

3. Ground Fault Interrupters (GFI's) — These protection devices interrupt or open a circuit when undesired current paths — "faults to ground" — are detected. These faulty paths are frequently people. GFI's are available on the market today. Ground fault interrupters can be easily adapted to FCC home wiring systems; however, additional development is needed before the following absolute requirements are fulfilled:

1. The device must fail safe.

2. The device must prevent electrical shocks greater than 10 mA between hot line and ground.

3. The device must be reasonably priced.

Obviously, combinations of the above could be utilized if ever required.

STATUS, PROBLEMS, AND ADVANTAGES

As stated before, the MSFC home wiring project is in the prototype phase, and two contracts have been completed for prototype hardware: One was a circuit breaker panel with a round wire service line and FCC distribution circuits, and the other was a surface-mounted baseboard system. Future contracts will probably be for: (1) interroom connections, (2) intrahouse cable routing and attachment techniques, and (3) interconnecting devices for equipment and special appliances.

There will be problems to surmount before FCC is established as a home wiring system, for example:

1. Establishing FCC electrical codes.

2. Unions and trades.

3. Architect and engineer acceptance.

4. Manufacturer and distributor acceptance.

5. Contractor and utility company acceptance.

6. Human resistance to change.

7. Massive changeover.

8. Safety methods.

9. Interroom routing.

10. Funding and time.

This is not intended to be a complete list, but it does indicate that many people, organizations, businesses, companies, manufacturers, and stock holders will be involved. Most of the problems will be "people problems." The seventh problem (massive changeover) — changing from round wire methods and hardware to FCC methods and hardware — will be gigantic, and no person alive today will live to see it completely solved. The technical problems, of which two are noted (safety and routing), will be very minor as they relate to the first seven problems. The last problem might be more appropriately listed as the "answer to all problems."

The most significant reason for implementing an FCC home wiring system, is low overall cost to the owner. Typical advantages of an FCC wiring system are:

1. Flexibility.
2. Surface mounting.
3. Polarized wiring.
4. Lower material cost.
5. Lower installation cost.
6. Less skilled labor required.
7. Thin or low profile.
8. In-line receptacle installation.

All of these advantages support the goal — lower cost. This list, like the previous "problem-list," is not a complete listing. FCC is very flexible; it easily folds around corners and angles. In addition to lowering new construction cost, surface-mounted FCC will drastically reduce the electrical cost of rehabilitating and remodeling existing buildings (homes, offices, schools, apartments, stores, and hospitals). With polarized wiring, any "mis-wiring" would be intentional, not accidental; and conductors can be easily traced and identified. Material costs will be reduced by "using less" in most cases; e.g., with a polarized system, it is conceivable that the third wire (the safety ground) might be eliminated; it is a parallel path back to the same point in the circuit breaker box. Installation costs will be lowered by minimizing on-site labor. Since the installation is simple, less skilled labor can be used. Less coordination will be involved in scheduling the different trades, such as carpenters, plumbers, electricians, and painters. The thinness of FCC makes it easy to conceal. For aesthetic reasons, it can be hidden on walls, under paper, under paint, behind paneling, and under floor coverings such as tile, carpet, linoleum, and rugs. FCC can be hidden under most interior, or exterior, finishes. Thin FCC can be stacked or layered for low-profile routing of many circuits. Receptacle installation time will be reduced considerably with the snap-on cover baseboard system (Fig. 3), and it will be zero with the extendable baseboard system (Figs. 6 and 7).

SUMMARY

As a part of the NASA Technology Utilization Program, MSFC engineers are in progress towards establishing FCC as a standard home wiring method. Prototype hardware has been manufactured and tested, and the technical problems involved in completing the home wiring project are within the state-of-the-art. The goal is a surface-mounted flat conductor cable home wiring system that is lower in cost, functional, safe, and aesthetically pleasing.

Figures 11 through 16 show some of the past, present and future history of electrical house wiring. Figure 11 shows electrical hardware which is part of the past; but much of it is still around today. Figure 12 shows hardware which is still standard practice in many cases; an adapter was used in bridging the old with the new. Modern homes now have safe polarized connectors (Fig. 13), when properly wired. Soon, an adapter (Fig. 14) will again be used to bridge the gap between the old and the new — an old three-prong plug and a new FCC baseboard system. It will be an easy and logical transition to establish flat plugs for round wire (Fig. 15). In the near future, an electrical house wiring system might be like that shown in Figure 16 — all flat.

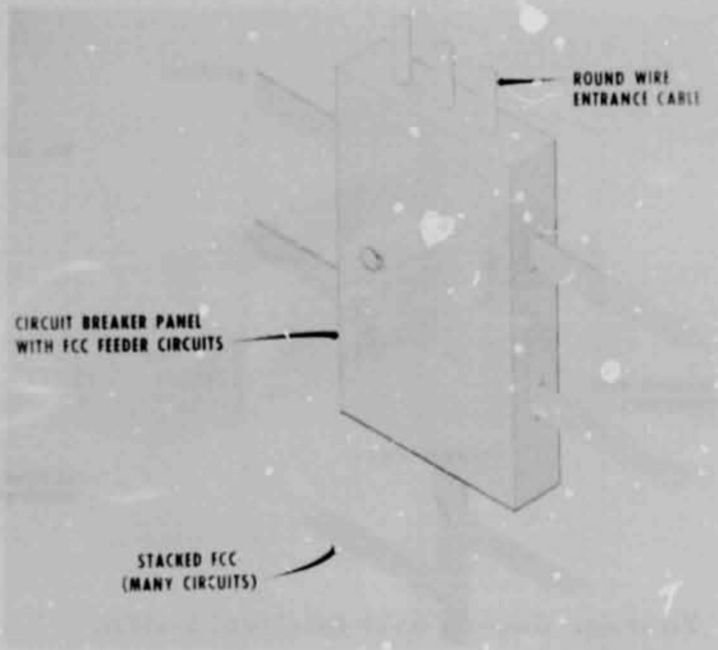

Figure 1. Circuit breaker panel.

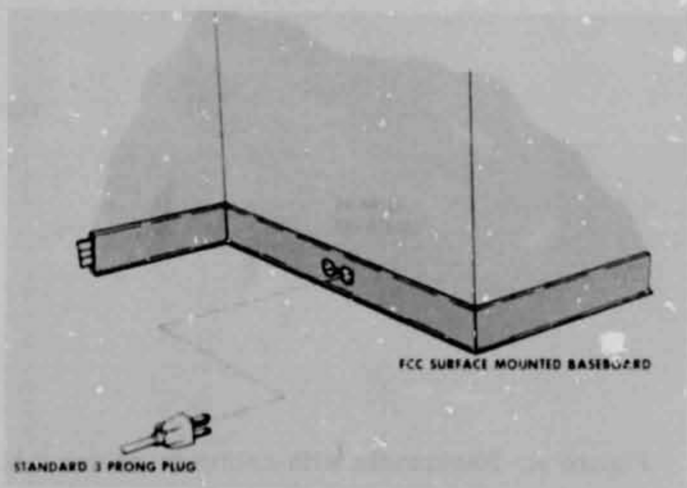

Figure 2. Surface-mounted baseboard.

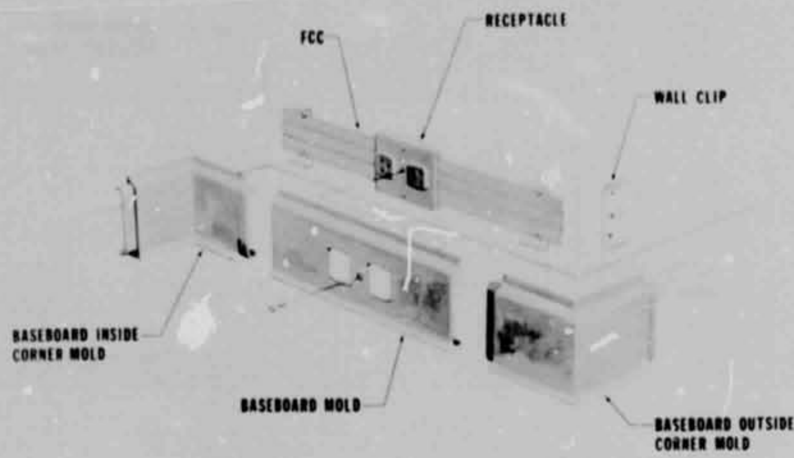

Figure 3. Snap-on cover baseboard system.

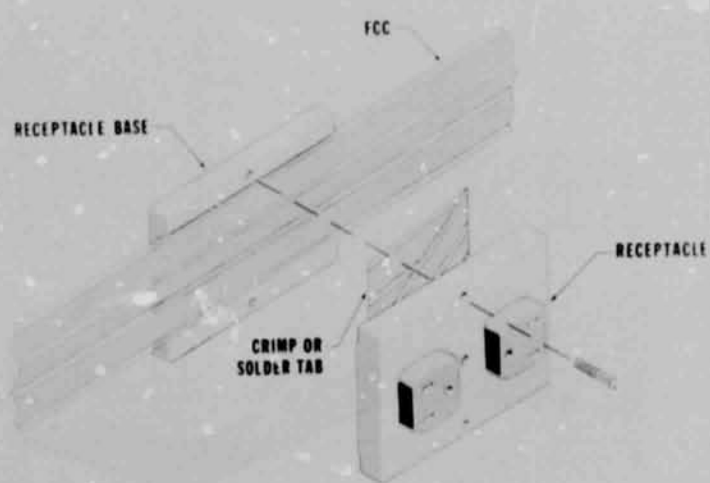

Figure 4. Receptacle with crimp or solder tab.

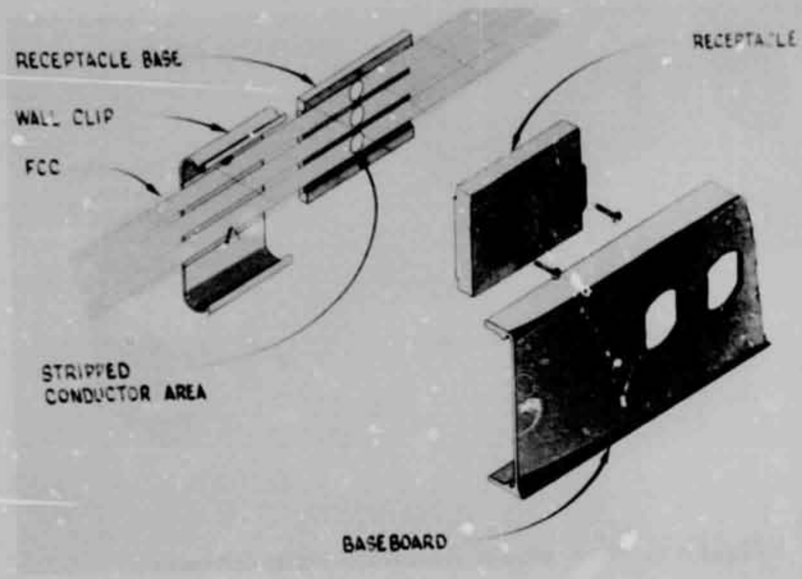

Figure 5. Receptacle with pressure contacts.

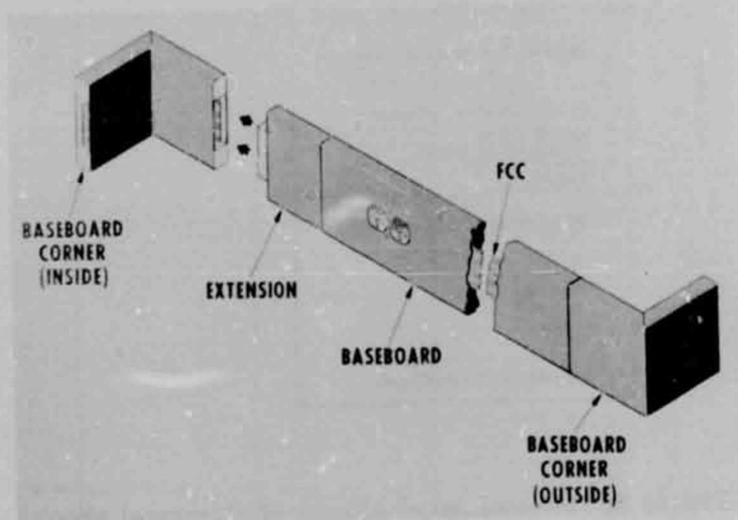

Figure 6. Extendable baseboard with standard receptacle.

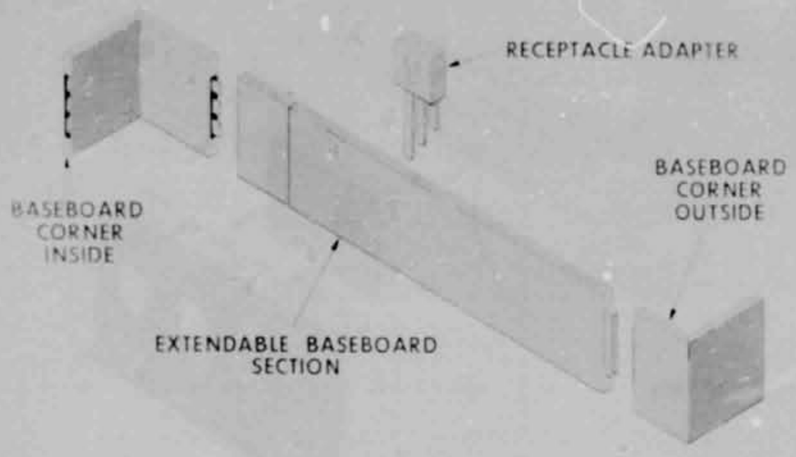

Figure 7. Extendable baseboard with adapter.

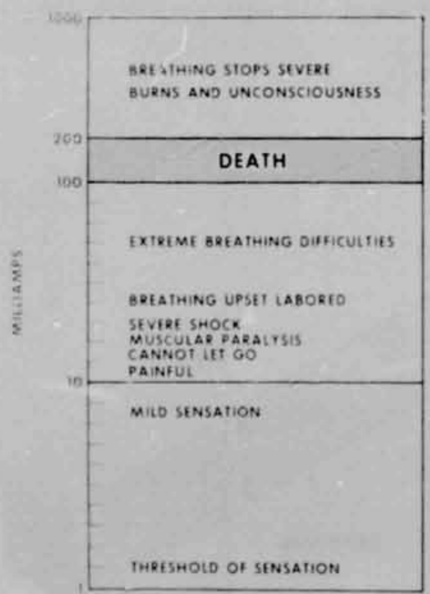

Figure 8. Physiological effects of electrical shock.

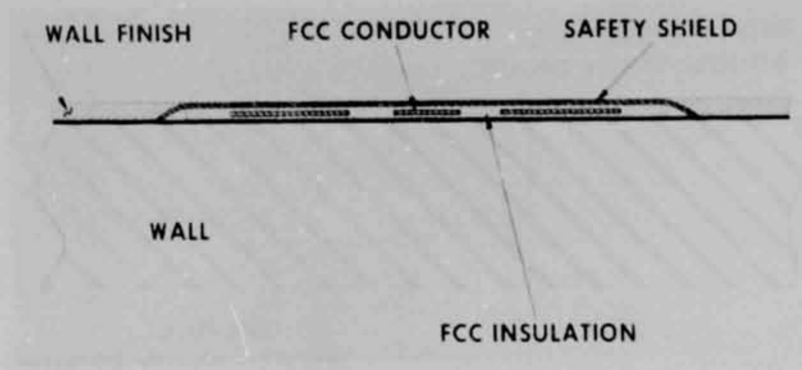

Figure 9. Cross section of FCC installed with safety shield.

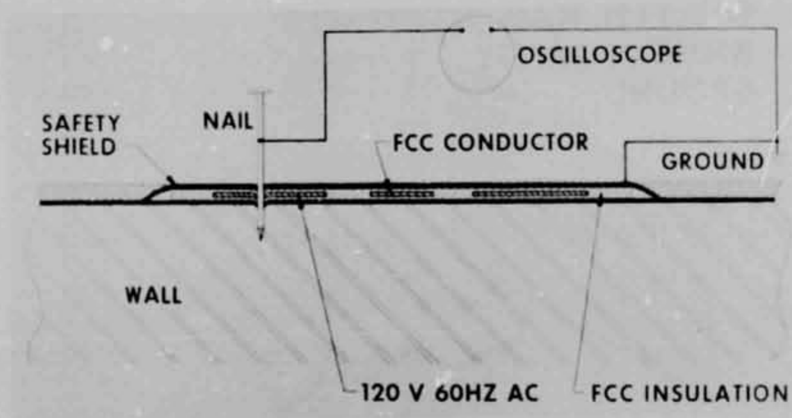

Figure 10. Test setup for FCC with grounded shield.

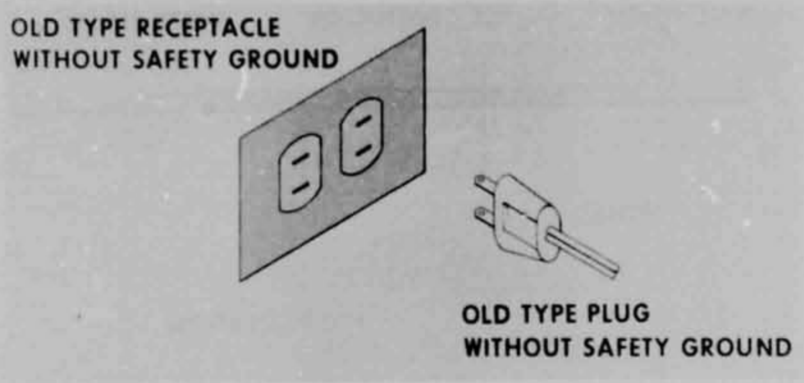

Figure 11. Standard nonpolarized duplex connector.

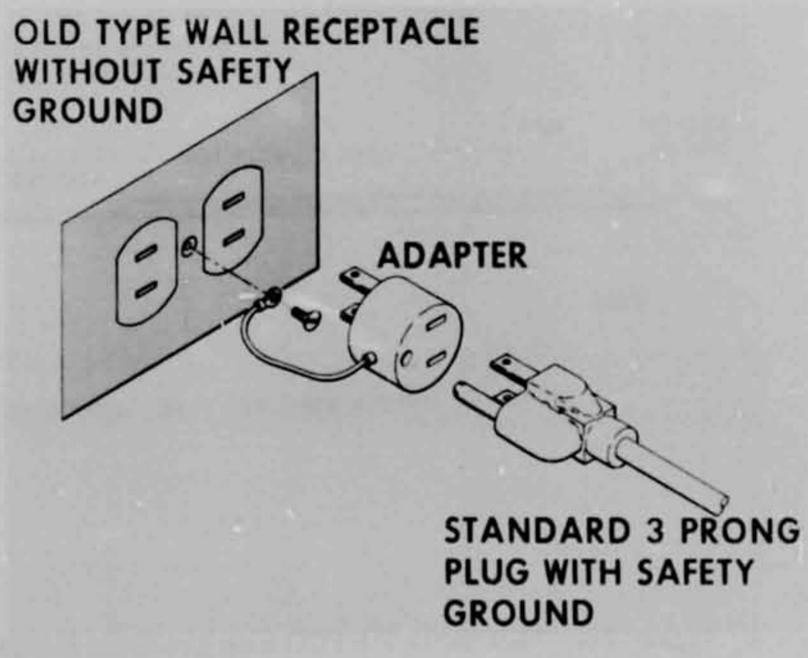

Figure 12. Nonpolarized duplex receptacle
with adapter for three-prong plug.

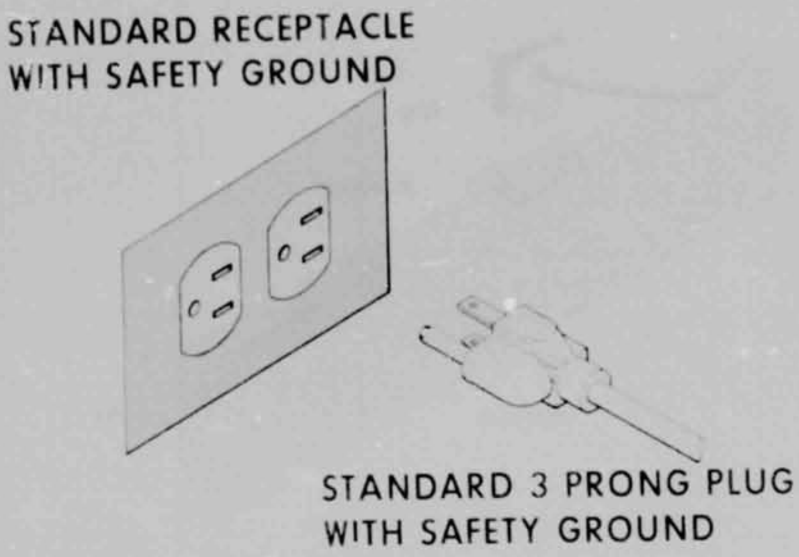

Figure 13. Standard polarized duplex receptacle with plug.

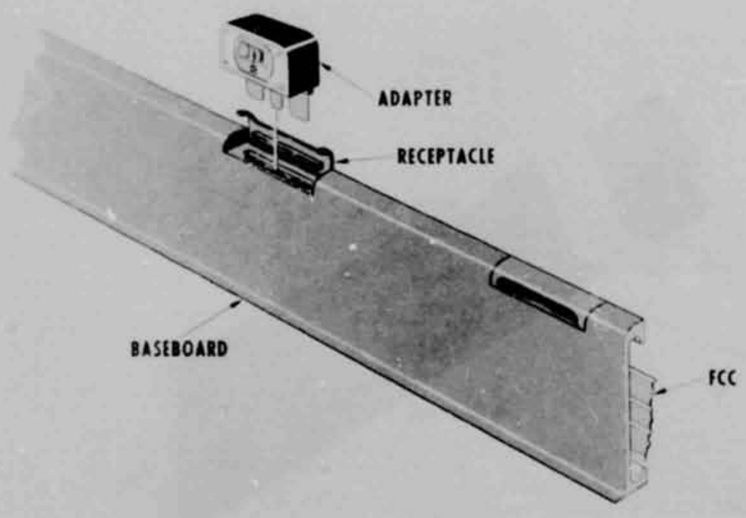

Figure 14. FCC baseboard with adapter for three-prong plug.

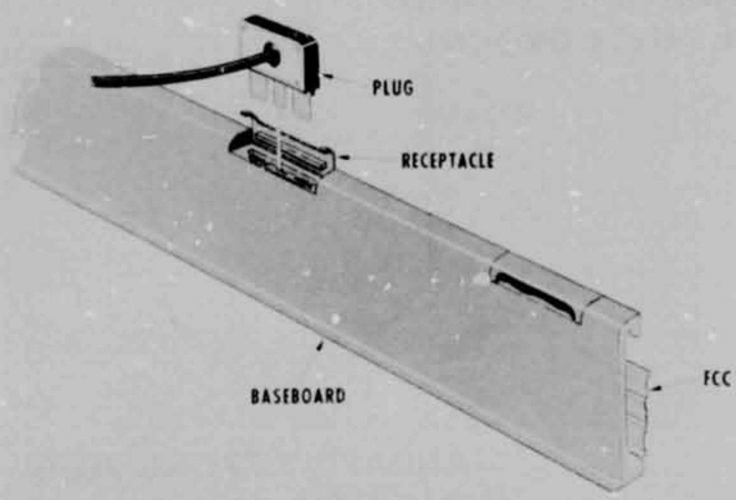

Figure 15. FCC baseboard with flat plug for round wire.

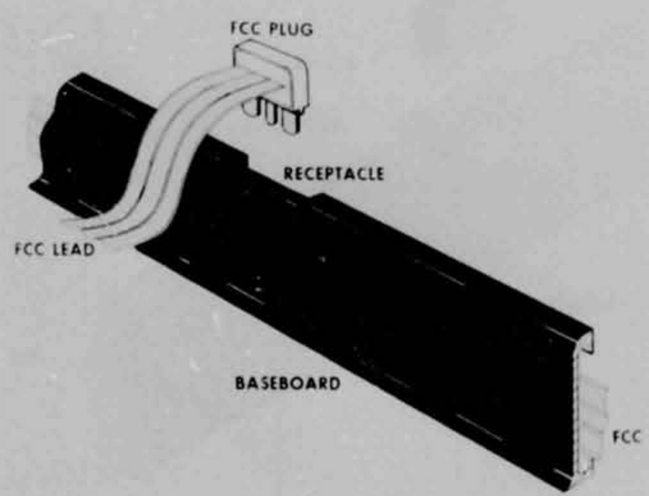

Figure 16. FCC baseboard with FCC plug and cable.

APPROVAL

SURFACE-MOUNTED FLAT CONDUCTOR CABLE FOR HOME WIRING

By James D. Hankins and James R. Carden

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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